Data Preparation in Energy-Economy-Agriculture Models

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Introduction (1)

- Top-down economic modeling for environmental policy analysis requires several types of data
  - Input-output tables
  - National income accounts
  - Energy balances
  - Energy technology characteristics
  - Agriculture and land use is increasingly important for questions related to climate policy
- Data collection effort depends on questions to be asked
  - Expand detail in sectors of interest and collapse detail in other areas
  - For some questions, especially on a global scale, level of detail provided by GTAP may be sufficient
  - For single-country studies, especially those focused on specific energy sectors, you may want to collect and process local data

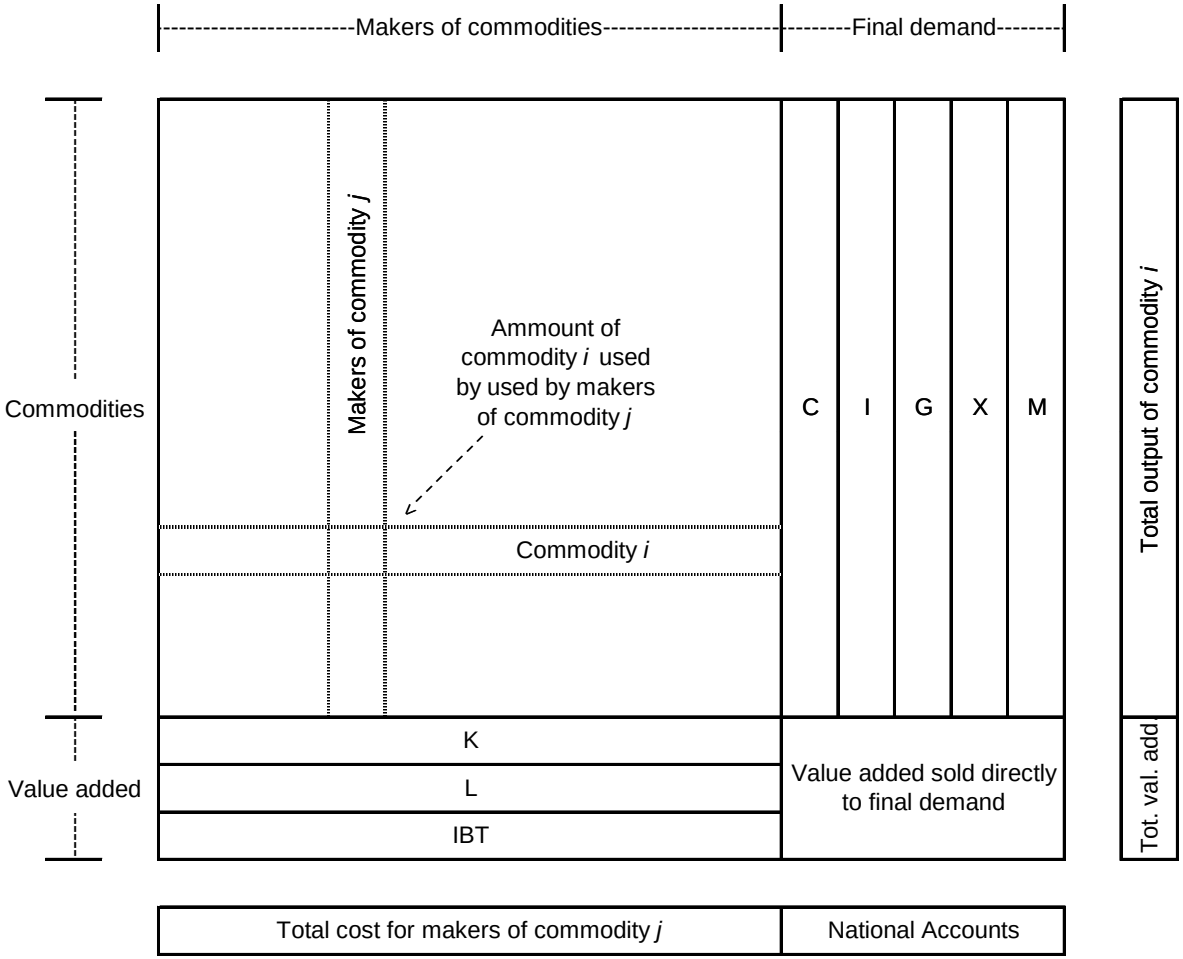
Introduction (2)

- Importance of physical flows
  - Energy
    - Demand for secondary fuels
    - Efficiency of transformation from primary to secondary fuels
    - Implied demand for primary fuels and resulting emissions
  - Agricultural products
    - Demand for food in calories
    - Efficiency of transformation from primary agriculture to animal products
    - Implied demand for land
- Coverage of all major classes of greenhouse gas mitigation options
  - Energy efficiency
  - Fuel switching
  - CO_2 capture and storage (CCS)
  - Non-CO_2 greenhouse gases
  - Land management, biofuels, carbon emissions from land use change

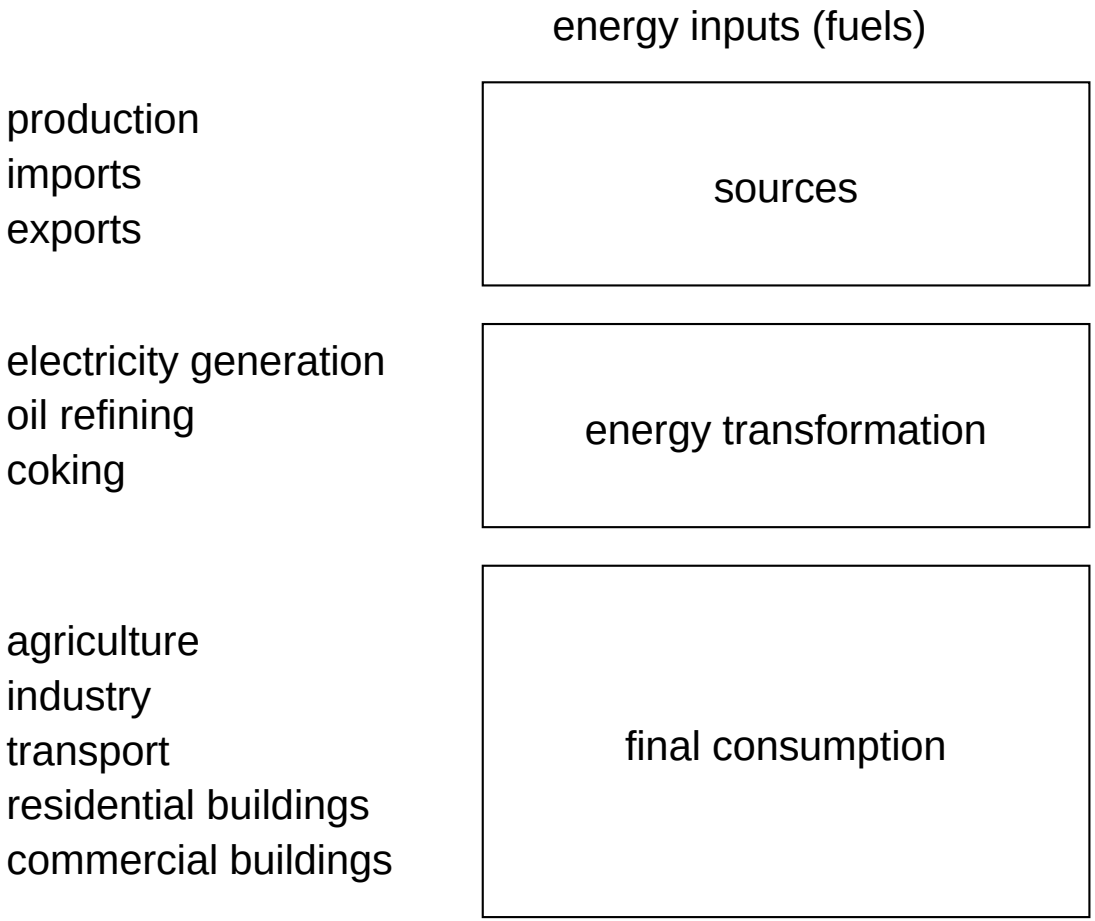
Energy-Economy Data

- Input-output tables
  - Each row is an input to production
  - Each column is a production activity or final demand activity (consumption, investment, international trade)
  - Can be constructed in either quantity or value terms
- National income accounts
  - Income must equal expenditure for various accounts: producers, consumers, investment, trade
  - Can be expressed in a matrix where row sums equal column sums
- Energy balances
  - Essentially an input-output table for energy
  - Expressed in energy quantities
- Energy technology characteristics
  - Efficiency in physical terms
  - Levelized cost to produce one unit of output (e.g., kWh)

Structure of Input-Output Table



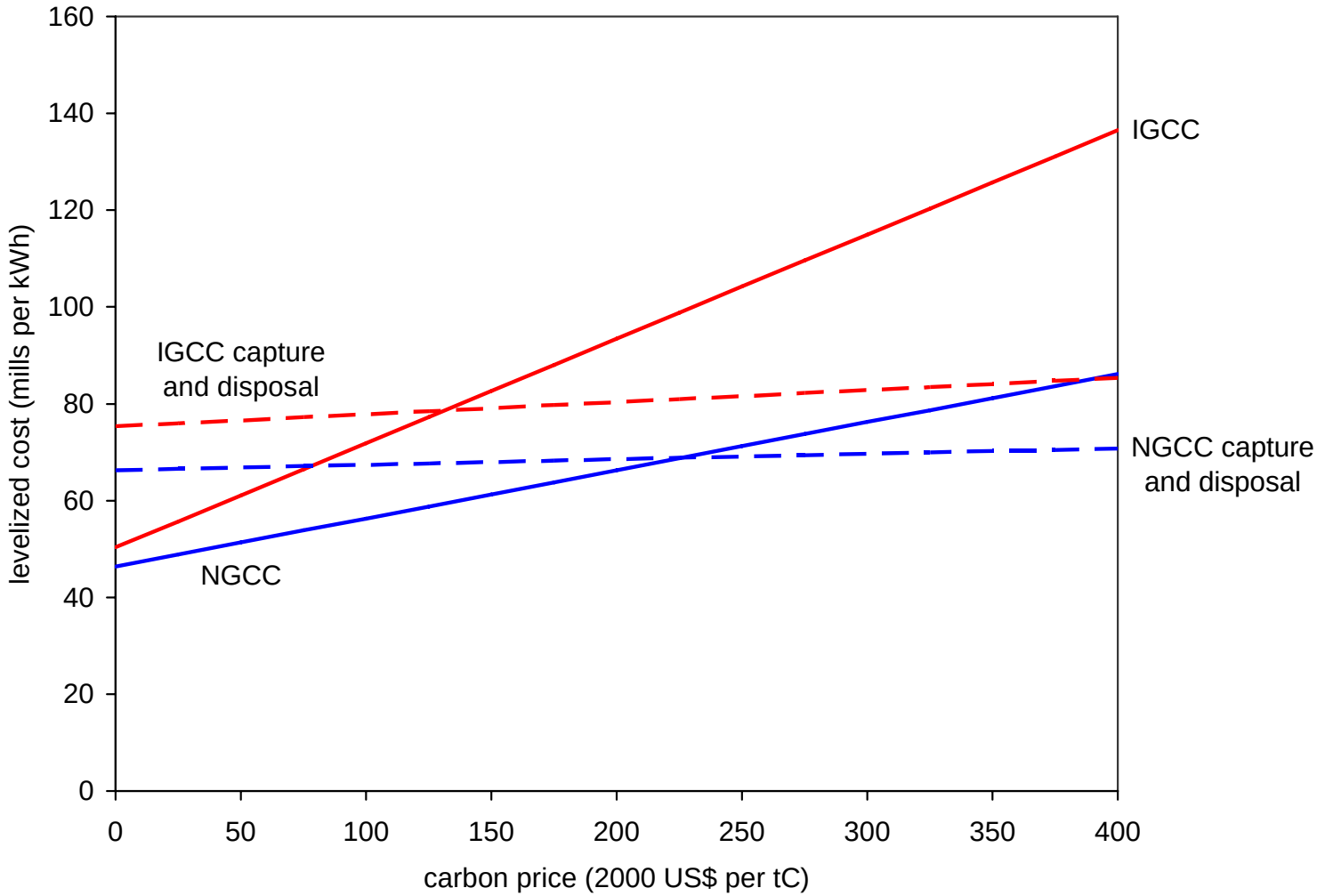
Structure of Energy Balance Table



Engineering cost assumptions for electricity generation technologies in SGM-USA (1990 US$)

			natural gas		coal			renewables	
Parameter	unit	oil	single cycle	NGCC	PC	IGCC	nuclear	hydro	wind
Operating in model base year?		yes	yes	no	yes	no	yes	yes	no
Economic assumptions									
fuel price	$/GJ	4.19	2.26	2.26	0.97	0.97			
interest rate	percent	10%	10%	10%	10%	10%	10%	10%	10%
Capital cost									
purchase cost of capital	$/kW	500	500	800	1,150	1,401	1,000	1,000	1,200
plant factor	percent	20%	40%	75%	75%	75%	75%	75%	20%
capital lifetime	years	20	20	20	20	20	20	20	20
interest plus depreciation	percent	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%	11.7%
levelized capital cost	mills/kWh	33.5	16.8	14.3	20.6	25.0	17.9	17.9	80.5
Fuel cost									
efficiency	percent	32%	36%	50%	32%	41%			
fuel cost per kWh	mills/kWh	47.6	22.9	16.4	10.8	8.6			
Operations and maintenance cost	mills/kWh	2.5	2.5	7.4	7.4	7.4	15.0	5.0	7.4
Levelized cost per kWh (total)	mills/kWh	83.6	42.1	38.1	38.7	41.0	32.9	22.9	87.9
CCS operational in base year?				no	no	no			
capture efficiency	percent			90%	90%	90%			
CO2 captured	kg-CO2/kWh			0.328	0.728	0.711			
capital cost	$/kg-CO2/h			921	521	305			
O & M cost	mills/kg-CO2			5.20	5.56	2.65			
energy required	kWh/kg-CO2			0.354	0.317	0.194			

Levelized Cost of Electricity as a Function of Carbon Price



Social Accounting Matrix (SAM) as an Organizing Tool

- Matrix structure to hold all benchmark (base-year) data
- Three major components
  - National income accounts (condensed SAM)
  - Use table (commodity x activity)
  - Make table (activity x commodity)
- Economic models usually have single-output production functions
- Matrix algebra can be used to transform use and make tables so that each activity produces only one commodity

Condensed Social Accounting Matrix (1990 USA)

	activities	commodities	primary factors	enterprises	households	government	capital	rest of world	
activities		**GROSS_OUTPUT** 9,790,599							9,790,599
commodities	**INTERMEDIATE_INPUTS** 4,269,660				**PCONS** 3,760,223	**GCONS** 847,785	**INVEST** 960,864	**EXPORTS** 543,179	10,381,711
primary factors	**VALUE_ADDED** 5,520,940								5,520,940
enterprises			**OVA** 1,823,076						1,823,076
households			**LABOR** 3,248,246	DIVIDENDS 1,068,577		GTR 808,000			5,124,823
government			**IBT** 449,618	CIT 140,500	PIT+SSTAX 1,143,300				1,733,418
capital				RE 613,999	PSAV 221,300	GSAV 77,633		NET_BORROWING 47,933	960,865
rest of world		**IMPORTS** 591,112							591,112
	9,790,600	10,381,711	5,520,940	1,823,076	5,124,823	1,733,418	960,864	591,112	

Note: numbers in blue are derived directly from an input-output table

Use and Make Tables

- An input-output table is constructed from a use (input) table and a make (output) table
  - Some statistical agencies provide the original use and make tables
  - Some agencies provide only the combined input-output table
- Use table
  - Looks like an input-output table
  - But there may be more than one production activity for some products (e.g., several ways to generate electricity)
- Make table
  - Each row is a production activity
  - Each column is a product or commodity

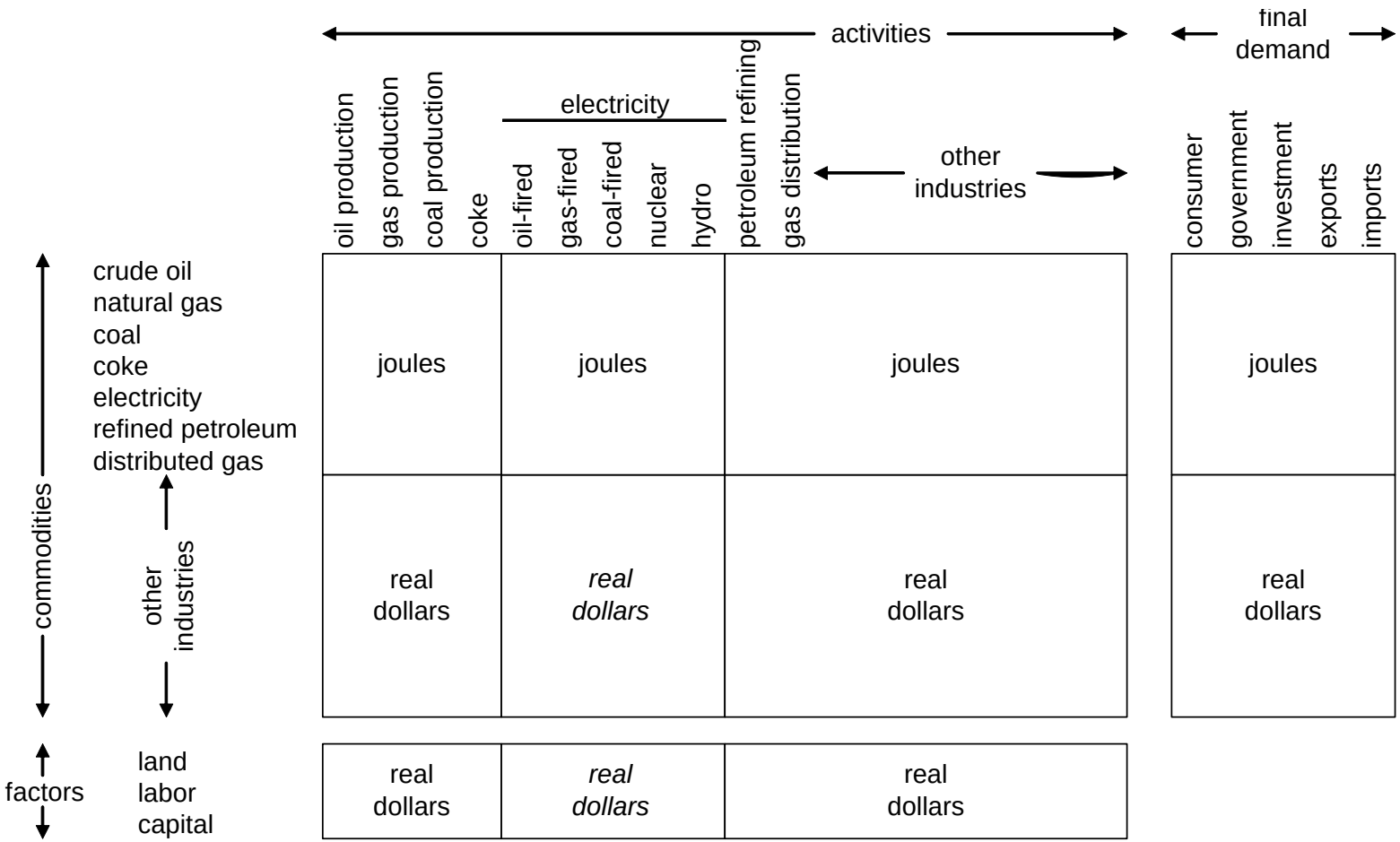
1997 energy make table for China (mtoe)

	Crude Oil	Natural Gas	Coal	Coke	Gases from Coal Transform	Refined Petroleum	Electricity	Heat
Oil and Gas Extraction	160.7	21.4						
Coal Mining			713.6					
Coke Ovens				90.3	11.7			
Blast Furnaces					13.7			
Petroleum Refineries						164.5		
Petrochemical Industry								
Gas Works		3.9		0.7				
Public Electricity Plants							95.8	
Autoproducer Electricity Plants							1.7	
Heat Plants								28.1
CHP Plants								
Production by Fuel	160.7	25.3	713.6	91.0	25.4	164.5	97.6	28.1

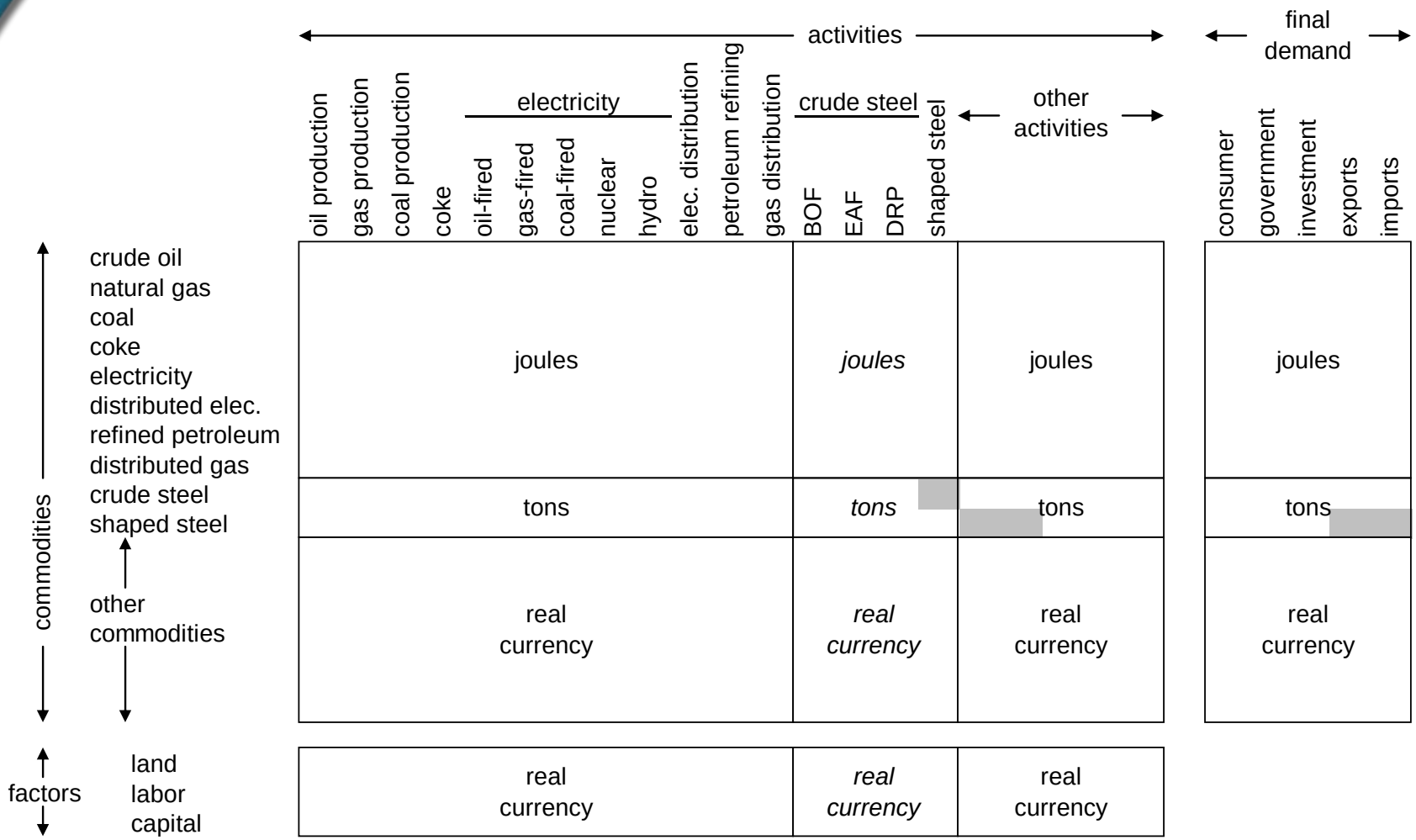
Hybrid Use Table

- Combines economic input-output data, energy balances, and energy technology characteristics into one table
- Sequence of calculations (used in SGM model)
  - Aggregate economic use and make tables to desired level of detail
  - Construct energy use and make tables from energy balance tables
  - Check that energy technology data is consistent with energy balances
  - Replace energy rows of economic use table with corresponding data from energy balances (hybrid use table)
  - Re-balance hybrid table in value terms so that row sums match column sums
  - Insert energy technology data

Structure of Hybrid Use Table



Hybrid Use Table with Steel Technologies



Documentation for Second Generation Model

SGM documentation can be found at:

http://www.epa.gov/air/sgm-sab.html

The Second Generation Model: Model Description and Theory, PNNL-15432 (PDF, 51 pp, 1566 KB)

The Second Generation Model: Data, Parameters, and Implementation, PNNL-15431 (PDF, 39 pp, 356 KB)

The Second Generation Model: Future Directions for Model Development, PNNL-15437 (PDF, 10 pp, 126 KB)

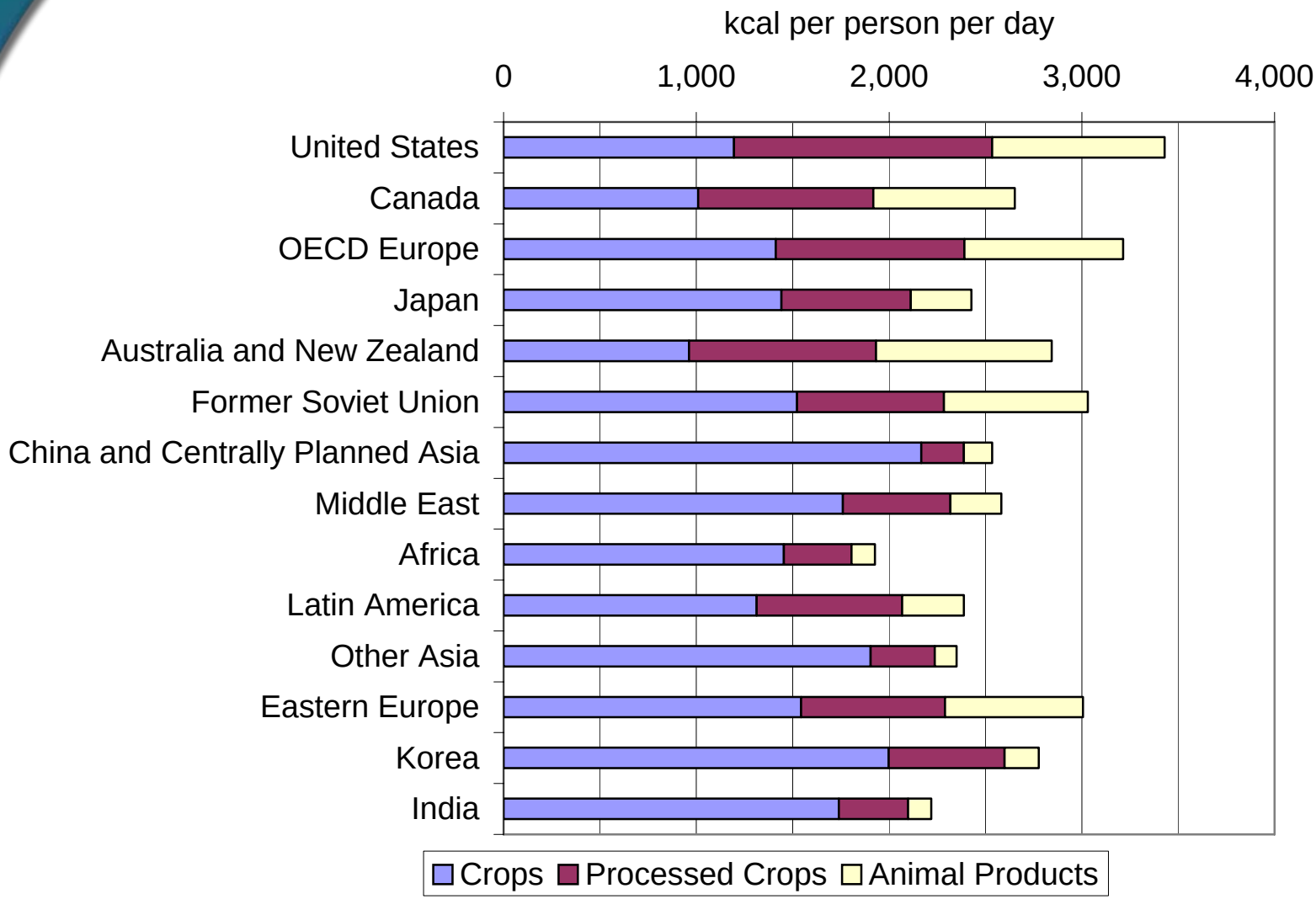
Agriculture-Forestry Data

- Agriculture-Forestry Data
  - Food balances
  - Land use data
  - Forest production
- Following slides provide a brief introduction to this data at a global level
- United Nations Food and Agriculture Organization (FAO) is the primary source of data
- Top-down general equilibrium models are being extended to include agriculture and forestry

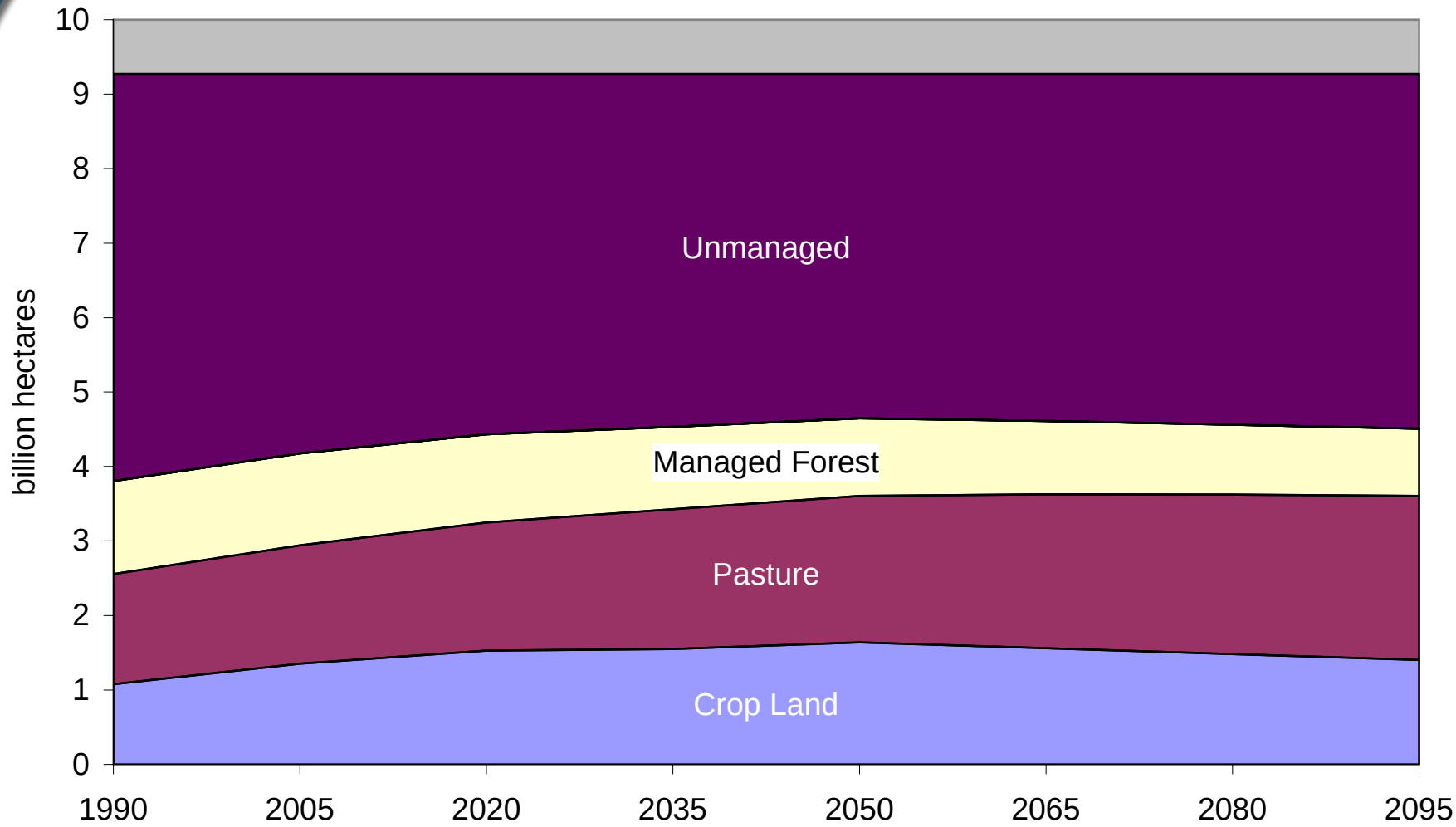
1990 Global Food Balance (kcal per person per day)

	Activity			Final Demand			
	Crops	Processed Crops	Animal Products	Food	Other Uses	Stock Change	Total Production
Crops	344	748	1,041	1,726	51	49	3,959
Processed Crops	0	0	2	532	80	-4	609
Animal Products	0	0	37	382	38	0	457

Food Consumption by AgLU Region



Land Use (without carbon policy)



Summary

- Benchmark data sets for top-down general equilibrium models can be represented as social accounting matrices (SAMs)
- The SAM structure is flexible so that detail can be expanded in areas of interest and collapsed elsewhere
- Bottom-up energy technology information can be placed in a SAM to represent interaction with the rest of the economy
- Modelers are working to include agricultural and forestry production in general equilibrium models
  - Important for analysis of climate policy
    - GHG emissions from agriculture
    - CO_2 sequestration in forests and soils
    - Climate impacts on agriculture and forest production
    - Potential for biofuels
  - GTAP effort
  - Energy Modeling Forum (EMF-22) land use subgroup